

Experimental Study on Water Evaporation of Layered Soil with Coarse-grained Interlayer

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Abstract

In this paper, quartz sand, loess and diatomite are used to study the influence of interlayer on evaporation process by changing the thickness and gradation of interlayer, for layered soil, coarse-grained interlayer has different thickness and gradation, and the properties of interlayer can be changed by mixing with other soil. The influence of interlayer factors on evaporation process can be determined by analyzing the relationship between evaporation rate and evaporation capacity with time, the results show that: (1) compared with homogeneous soil, when the soil contains coarse-grained interlayer, it will inhibit the evaporation of soil moisture; (2) When the median particle size of the sand intercalation layer is equal, the worse the gradation of the interlayer, the higher the evaporation rate; (3) With the increase of the mixing proportion of loess and diatomite in the sand layer, the corresponding evaporation rate increases, and when the mixed diatomite reaches a certain proportion, it will promote the evaporation.

Keywords

Soil Water Evaporation; Evaporation Rate; Evaporation Capacity; Coarse Grained Interlayer.

1. Introduction

Soil moisture evaporation is one of the main processes of soil atmosphere material and energy exchange. For natural soil, the driving force of evaporation comes from climate, especially arid climate. Because evaporation will change the content and distribution of water in soil, and then lead to the change of engineering properties of soil, many engineering, environmental and agricultural problems are directly or indirectly related to evaporation. The decrease of soil moisture directly leads to the shrinkage deformation and even dry crack of soil, which leads to land settlement, deformation of ground infrastructure and facilities, and damage of foundation works; In arid and semi-arid areas, under the condition that the groundwater contains salt water, evaporation will make the salt water migrate to the surface of the soil. After the salt water in the soil is lost, high concentration of salt will be left to accumulate on the surface to form a salt shell, which will affect the growth of crops. Therefore, the study of the water change law of soil evaporation is of great significance to formulate a reasonable crop irrigation scheme, evaluate the impact of evaporation on geotechnical engineering properties, and solve the problem of soil salinization.

For the water evaporation of layered soil, some scholars have obtained a large number of unified results through research. Unger studied the effect of gravel layer on evaporation by arranging 2.5cm thick gravel layers at 0cm, 5cm, 15cm and 25cm of sandy loam and clay loam. The results showed that the evaporation rate of 0cm and 5cm was slower than that of the control group, while the evaporation rate of 15cm and 25cm was larger than that of the control group. Shokri et al. Showed that compared with the uniform hydrophilic column, the hydrophobic layer in the soil profile interrupted the water flow and reduced the water

evaporation. Wang studied the capillary water rise of layered soil through indoor soil column simulation test. The results show that the sand layer has an obvious barrier effect on the capillary water rise height, capillary rise rate and groundwater recharge. Shi studied soil evaporation under the condition of groundwater through indoor experiments. The results show that for the soil column with sand layer, the evaporation intensity decreases with the increase of sand layer thickness, while for the soil column with surface sand layer, it increases with the increase of sand layer thickness, which is inconsistent with Gardner's conclusion that the surface sand layer will inhibit evaporation. The author analyzes that the reason may be that the sand used is natural sand, The grading is good and plays a good role in heat conduction. Huang set up three kinds of layered soil columns with different thickness using sand and loess. The results show that the cumulative evaporation of homogeneous soil columns is much greater than that of other soil columns with interlayer. Yu and others carried out large-scale model tests to explore the influence of clay interlayer on water and salt movement. The results show that the clay layer has good water retention and salt resistance, and has an obvious barrier effect on the phenomenon of salt accumulation in surface soil. Zhai studied the effect of salt and water barrier with zeolite, ceramsite, vermiculite, sea foam stone wool and river sand as interlayer through indoor one-dimensional soil column evaporation test. The results show that the five interlayer have inhibitory effect on evaporation, and the zeolite interlayer has the best effect of water and salt barrier.

In order to explore the influence of coarse-grained interlayer on soil moisture evaporation in multi-layer soil, quartz sand, loess and diatomite are used in this paper. The indoor experimental research is carried out by changing the gradation of interlayer and the mixing ratio of other soil in interlayer, and its influence on soil moisture evaporation is discussed and analyzed.

2. Materials and Methods

The materials used in the test are mainly loess, diatomite and quartz sand. The specific parameters are shown in Table 1.

Table 1. Basic physical properties of samples

Sample (mm)	Maximum dry density (g/cm ³)	specific gravity	LL (%)	PL (%)	Plasticity index (%)	Sand (%)	Silt (%)	Clay (%)
Loess	1.46	2.67	28.00	12.00	16.00	26	63	11
Diatomite	0.42	2.26	-	-	-	4	55	41
0.1-0.25 Sand	1.61	2.48	-	-	-	100	-	-
0.25-0.5 Sand	1.61	2.55	-	-	-	100	-	-
0.5-1 Sand	1.58	2.63	-	-	-	100	-	-
1-2 Sand	1.59	2.70	-	-	-	100	-	-

In order to obtain quartz sand with different gradation and control the same particle size, the quartz sand with different particle size is mixed in different proportions and the particle size grading curve is drawn, and then the values of Cu and Ccare calculated. The obtained Cu values are 8.82, 4.3 and 1.96 respectively. In this test, PVC columns with a height of 33cm and an outer diameter of 11cm are used. The bottom is connected with a pipe sleeve with an inner diameter of 11cm. Five small holes with a diameter of 2mm are drilled at the lower part of the pipe sleeve in hexagonal distribution. The gaps are glued with waterproof glass glue, and the filter paper is

placed at the bottom of the evaporation tray to prevent particles in the evaporation tray from falling. Open the air at 5cm, 15cm and 25cm of the column to take soil samples to measure the moisture content at different depths during the evaporation process. In order to maintain the accuracy of the data, it is necessary to configure soil samples with a certain moisture content within a certain error range. Take out the prepared soil samples and fill them into the column with the same quality as the soil samples for measuring the moisture content, so as to ensure the normal progress of the evaporation process. The test materials are delta loess, diatomite and quartz sand with particle sizes of 1-2mm, 0.5-1mm, 0.25-0.5mm and 0.1-0.25mm respectively. The specific test group settings are shown in Table 2.

Table 2. Evaporation tray experimental group setting

Gpoup	Soil condition	Interlayer condition
1	Only loess	No interlayer
2	Loess and 10cm, d50 = 0.5 quartz sand interlayer	Cu=8.82, 4.3, 1.96
3	Loess and 10cm, 0.25-0.5mm quartz sand interlayer	Quartz sand: loess = 1:0 / 0.2/0.4/0.6/0.8/1
4	Loess and 10cm, 0.25-0.5mm quartz sand interlayer	Quartz sand: diatomite = 1:0 / 0.2/0.4/0.6/0.8/1

In order to better control the column density, the samples are filled in layers. Place the sample in the water tank and gradually raise the water level in the water tank to saturate the sample. Place the sample on the plane and use a 200W bulb and a powerful fan to provide light and wind speed on the soil surface to speed up the evaporation process of the soil. The sample is shown in Figure 1:



Fig. 1 a) Interlayer with different gradation b) Interlayer with different loess mixing ratio c) Interlayer with different diatomite mixing ratio

After the test, the soil samples in the evaporation column are weighed at different times with a weighing module composed of Mettler weighing sensor (accuracy 0.1g) and webowt weighing display instrument. The water loss in a certain time is obtained by weighing, and then the ratio of EA to EP at different times and the moisture content at different times are calculated. In order to ensure the accuracy of the data, the data shall be recorded every 4 hours 3 days after the start of the test, and then the time for recording the data shall be gradually extended.

3. Results and Discussion

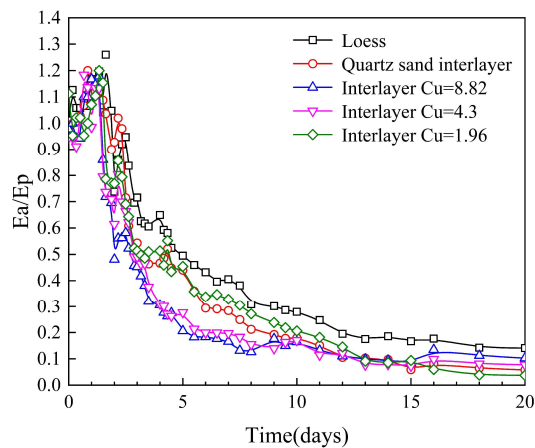


Fig. 2a) Variation of E_a/E_p of interlayer with different gradation with time

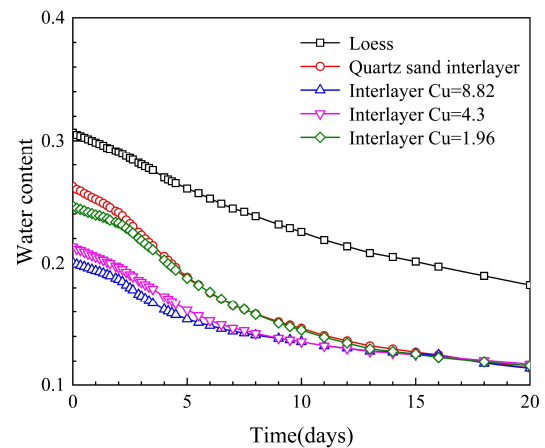


Fig. 2b) Variation of water content of interlayer with different gradation with time

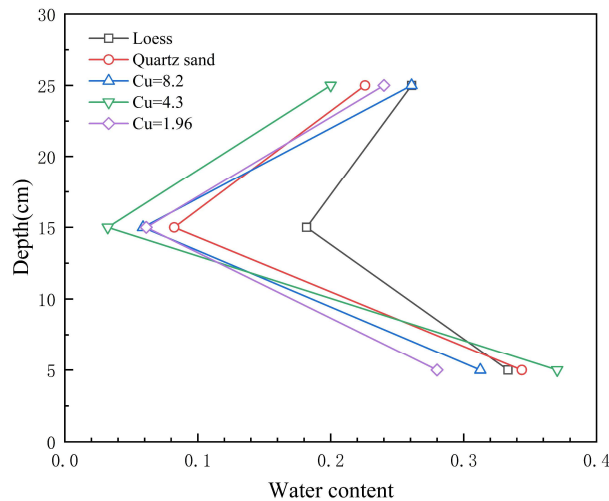


Fig. 2c) Water content at different depths at the 7th day of evaporation of interlayer with different gradation

Fig. 2a) shows the change of E_a/E_p with time in the evaporation process of pure loess soil column, intercalated quartz sand and intercalated $C_u = 8.82$, $C_u = 4.3$ and $C_u = 1.96$. It can be seen from the figure that in the constant rate evaporation stage of the evaporation process, the E_a / E_p value of each treatment is about 1.0-1.2, and there is no obvious difference; Then enter the second stage of the evaporation process. It can be seen that when the E_a/E_p value is the same, the corresponding evaporation time is $C_u = 8.82$, $C_u = 4.3$, $C_u = 1.96$, pure quartz sand interlayer and loess treatment from short to long. When the evaporation process is the same time, the E_a/E_p value is loess, pure quartz sand interlayer, $C_u = 1.96$, $C_u = 4.3$ and $C_u = 8.82$ from large to small, indicating that in the deceleration rate stage, The better the gradation of the interlayer, the smaller the corresponding evaporation rate, and the worse the gradation of the interlayer, the greater the corresponding evaporation rate. The reason may be that when the sand gradation in the interlayer is poor, there are larger pores between sand particles and sand particles, which corresponds to larger water content in the process of saturation. When evaporation is carried out, with the continuous reduction of water in the Loess above the interlayer, The interlayer with higher moisture content can provide water for the soil above the interlayer faster, the water loss is faster, and the E_a/E_p value is higher. With the continuous evaporation, a large amount of soil moisture in the upper part of the interlayer is lost, and the

evaporation process of each treatment enters the residual evaporation stage. In the early stage of the residual evaporation stage, the worse the interlayer gradation, the greater the corresponding E_a/E_p value. In the later stage of the residual evaporation stage, the better the interlayer gradation, the greater the corresponding E_a/E_p value, and the turning time is about the 10th day. The reason may be that the moisture is lost in the form of water vapor in the residual evaporation stage, For the treatment with poor interlayer grading, it can not reach the inflow value of this layer of soil; For the treatment with better interlayer grading, the water can maintain a certain hydraulic connection after the interlayer, and the water in the soil under the interlayer can also migrate upward in a small amount, showing a larger E_a/E_p value.

Fig. 2b) shows the change of mass moisture content with time when pure loess soil column, interlayer is quartz sand and interlayer $C_u = 8.82$, $C_u = 4.3$ and $C_u = 1.96$. Since the material density of soil mass at the upper part of each treatment interlayer is the same as that at the lower part of the interlayer, this moisture content can be regarded as the change of moisture content in the interlayer with time. It can be seen from the figure that in the constant rate evaporation stage corresponding to Fig. 1, the change of moisture content of each treatment is relatively gentle, At this time, the water is mainly due to the loss of water in the soil above the interlayer; On the third day of evaporation, the slope of the water content curve increases obviously, indicating that a large amount of water in the interlayer moves upward and gradually dissipates; At about the 10th day of the evaporation process, the water content curve tends to be flat again. At this time, the water in the soil under the interlayer begins to migrate upward. However, due to the existence of the interlayer, the hydraulic connection is not smooth, and the water loss is relatively slow.

Fig. 2c) shows the moisture content of different depths corresponding to the treatment of non graded interlayer on the 7th day of evaporation. It can be seen from the figure that the pure loess soil column and interlayer are quartz sand and the treatment of interlayer $C_u = 8.82$, $C_u = 4.3$ and $C_u = 1.96$. At this time, the moisture content of surface layer and interlayer are 0.26, 0.22, 0.20, 0.2, 0.24 and 0.18, 0.08, 0.03, 0.05 and 0.07 respectively. The worse the grading of sand layer, the greater the corresponding moisture content, Thus, it can provide water for the upper soil faster, corresponding to a larger E_a/E_p value.

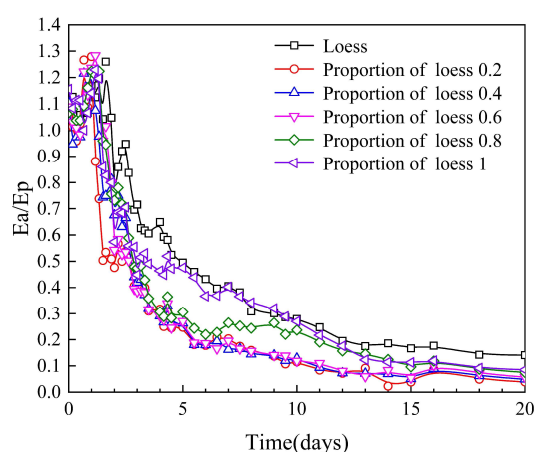


Fig. 3a) Variation of E_a/E_p of interlayer with different loess blending ratio with time

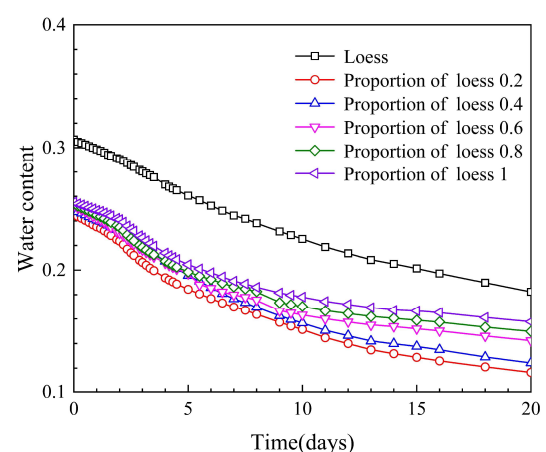


Fig. 3b) Variation of water content of interlayer with different loess blending ratio with time

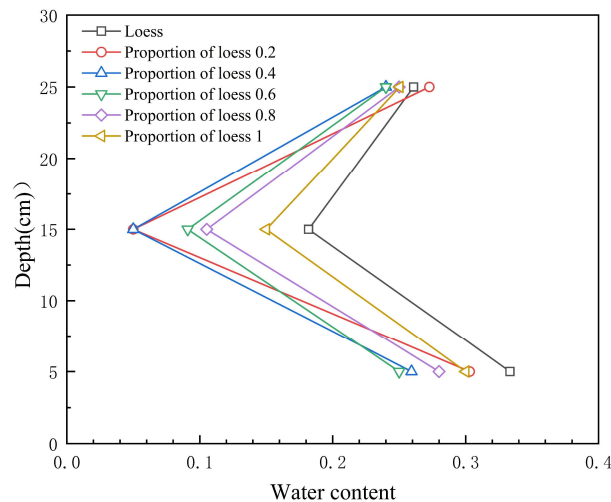


Fig. 3c) Water content at different depths at the 7th day of evaporation of interlayer with different loess blending ratio

Fig. 3a) shows the change of EA / EP value with evaporation process in the sixth middle treatment with different proportions of loess mixed in the interlayer. It can be seen from the figure that in the constant rate evaporation stage of the evaporation process, the EA / EP value remains about 1.0-1.3, which is roughly equal; As the evaporation continues to enter the deceleration rate stage, under the condition of the same EA / EP value, the corresponding time of the evaporation process from small to large is loess blending ratio 0.2, loess blending ratio 0.4, loess blending ratio 0.6, loess blending ratio 0.8, loess blending ratio 1 and loess respectively. The larger the Loess blending ratio in the interlayer, the longer the evaporation time corresponding to the same EA / EP value, and when the evaporation process time is the same, EA / EP values from small to large are loess blending ratio 0.2, loess blending ratio 0.4, loess blending ratio 0.6, loess blending ratio 0.8, loess blending ratio 1 and loess respectively, indicating that in the deceleration rate stage, the larger the Loess blending ratio in the interlayer, the higher the corresponding evaporation rate. The reason may be that when loess is mixed in the sand layer, the corresponding water content increases with the increase of loess blending ratio, The interlayer with higher moisture content can provide the water required for evaporation faster for the soil above the interlayer. Secondly, the higher the proportion of loess, the better the hydraulic connectivity between the lower part of the soil column interlayer and the soil above the interlayer. On the contrary, the smaller the proportion of loess will destroy the hydraulic connectivity between the soil below the interlayer and the soil above the interlayer. The water in the soil below the interlayer cannot migrate upward in time, resulting in a small EA / EP value in the evaporation process; In the residual stage of the evaporation process, the EA / EA value of each treatment does not change significantly. The EA / EP values from small to large are loess blending ratio 0.2, loess blending ratio 0.4, loess blending ratio 0.6, loess blending ratio 0.8, loess blending ratio 1 and loess respectively, indicating that the larger the Loess blending ratio in the sand mixed layer in the residual stage, the higher the evaporation rate.

Fig. 3b) shows the change of water content with time under the six treatments of loess, loess blending ratio 0.2, loess blending ratio 0.4, loess blending ratio 0.6, loess blending ratio 0.8 and loess blending ratio 1. It can be seen from the figure that with the increase of intercalated loess blending ratio, the overall water content also increases, and the water content curve shows the form of slow decrease, then the rate of decrease accelerates and then slowly decreases, The turning point is about the second and sixth day of the evaporation process. At the end of the

evaporation process, the treatment with higher loess content in the sand layer corresponds to higher water content.

Fig. 3c) shows the water content of different depths corresponding to the interlayer with different loess blending ratio on the 7th day of evaporation. It can be seen from the figure that the water content of loess, loess blending ratio 0.2, loess blending ratio 0.4, loess blending ratio 0.6, loess blending ratio 0.8 and loess blending ratio 1 are six treatments. At this time, the water content of surface layer and interlayer are 0.26, 0.27, 0.24, 0.24, 0.25, 0.25 and 0.18, 0.05, 0.05, 0.09, 0.10 and 0.15 respectively, The larger the proportion of loess mixed in the sand layer, the higher the corresponding water content, and can better maintain the continuity of the water potential of the whole soil profile, corresponding to the larger evaporation rate and water content of the whole.

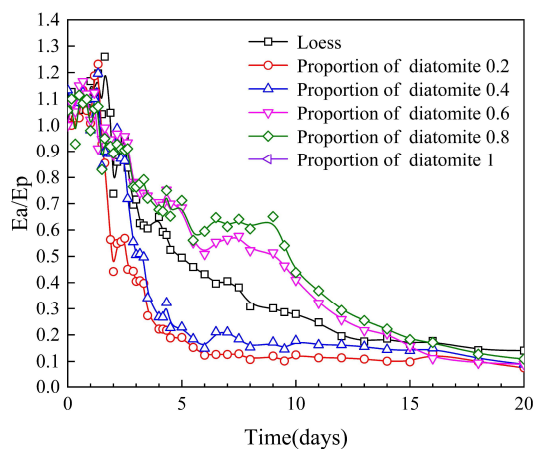


Fig. 4a) Variation of E_a/E_p of interlayer with different diatomite blending ratio with time

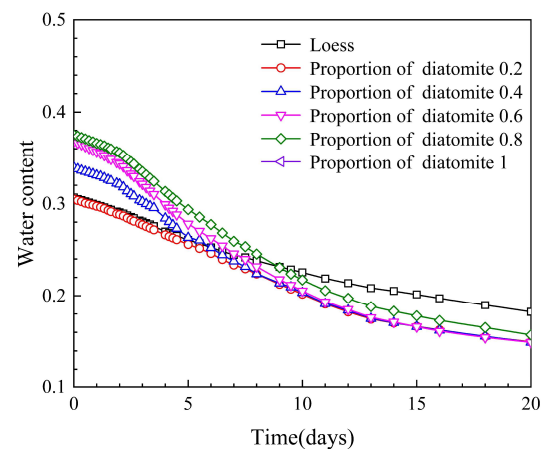


Fig. 4b) Variation of water content of interlayer with different diatomite blending ratio with time

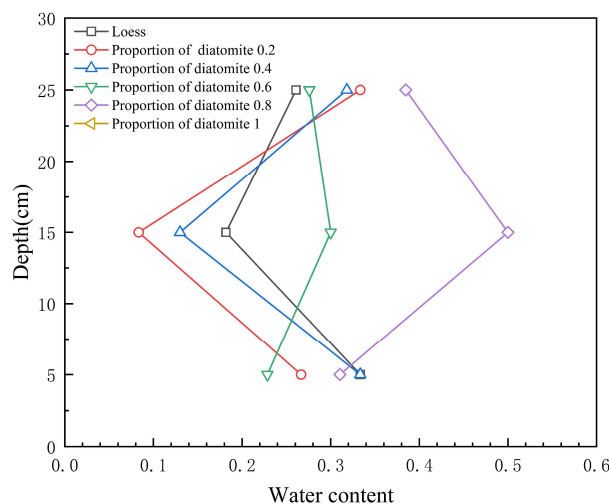


Fig. 4c) Water content at different depths at the 7th day of evaporation of interlayer with different diatomite blending ratio

Fig. 4a) shows the change of interlayer E_a / E_p value with the evaporation process of different diatomite mixing ratio. It can be seen from the figure that in the constant rate stage of the evaporation process, the evaporation rate remains unchanged at 1.0-1.2; When entering the deceleration rate evaporation stage, under the same E_a / E_p value, the corresponding evaporation time from short to long is diatomite mixing ratio 0.2, diatomite mixing ratio 0.4, loess, diatomite mixing ratio 0.6 and diatomite mixing ratio 0.8 respectively. When the

evaporation process enters the same time, the EA / EP value from small to large is diatomite mixing ratio 0.2, diatomite mixing ratio 0.4, loess, diatomite mixing ratio 0.6 and diatomite mixing ratio 0.8 respectively, It shows that the larger the proportion of diatomite in the sand inclusion layer, the greater the corresponding evaporation rate, and when the diatomite mixing ratio is 0.6 and 0.8, the corresponding EA / EP value is greater than that of loess soil column. The reason is that diatomite has good water retention performance, indicating that the evaporation rate of diatomite mixing ratio 0.6 and diatomite mixing ratio 0.8 is higher than that of pure loess treatment, When diatom is added into the interlayer, it will promote the evaporation process. With the continuous evaporation, the decline rate of EA / EP curve slows down, and the evaporation enters the residual evaporation stage.

Fig. 4b) shows the change of water content of interlayer with different diatomite mixing ratio with time. It can be seen from the figure that the change range of water content curve in the first stage is relatively small. The water content from large to small are diatomite mixing ratio 0.8, diatomite mixing ratio 0.6, diatomite mixing ratio 0.4, loess and diatomite mixing ratio 0.2 respectively, indicating that the higher the proportion of sand layer mixed with diatomite, the larger the corresponding overall average water content, The larger the corresponding EA / EP value is, the greater the decrease range of the water content curve increases when the evaporation enters about the third day, and the overall average water content of each treatment changes in the later stage of the evaporation process. At this time, the water content is loess, diatomite mixing ratio 0.8, diatomite mixing ratio 0.6, diatomite mixing ratio 0.4 and diatomite mixing ratio 0.2 respectively. The turning time is about the seventh day when the evaporation enters, The reason may be that compared with the stable evaporation of pure loess soil sample, the maximum dry density of diatomite is relatively small, which shows that the treatment quality water content of diatomite mixed in the interlayer is higher.

Fig. 4c) shows the moisture content of different depths corresponding to the interlayer with different diatomite mixing ratio on the 7th day of evaporation. It can be seen from the figure that the loess, diatomite mixing ratio is 0.2, diatomite mixing ratio is 0.4, diatomite mixing ratio is 0.6 and diatomite mixing ratio is 0.8. At this time, the corresponding moisture content of the surface layer is 0.26, 0.33, 0.32, 0.28 and 0.38 respectively, and the corresponding moisture content of the interlayer is 0.18, 0.08, 0.13, 0.3 and 0.5 respectively, The moisture content of the interlayer from small to large is diatomite mixing ratio 0.2, diatomite mixing ratio 0.4, loess, diatomite mixing ratio 0.6 and diatomite mixing ratio 0.8 respectively, which shows that the higher the proportion of sand layer mixed with loess, the greater the moisture content in the evaporation process, and when the mixing ratio reaches 0.6, the moisture content in the interlayer will be greater than that in the corresponding position of loess, so the evaporation rate will be higher in the evaporation process.

4. Conclusion

In this paper, the influence of interlayer in evaporation process is studied through soil evaporation test of evaporation column. The results show that:

- (1) Compared with homogeneous soil, when the soil contains coarse-grained interlayer, it will inhibit the evaporation of soil water.
- (2) When the median particle size of the sand intercalation layer is equal, the worse the gradation of the interlayer, the higher the evaporation rate, this is due to the corresponding water content in different interlayer.
- (3) When loess and diatomite are mixed into the coarse-grained interlayer, the corresponding evaporation rate increases with the increase of the mixing proportion of loess and diatomite, and the evaporation will be promoted when the mixed diatomite reaches a certain proportion.

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